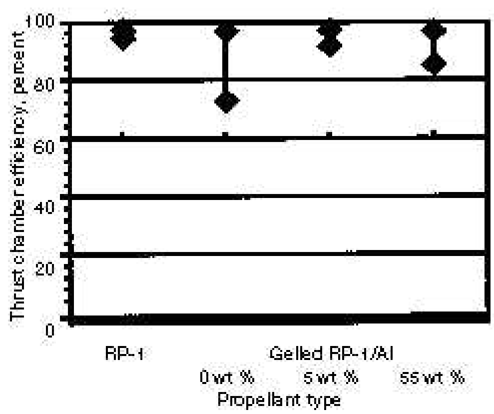
# Lessons Learned With Metallized Gelled Propellants

During testing of metallized gelled propellants in a rocket engine, many changes had to be made to the normal test program for traditional liquid propellants. The lessons learned during the testing and the solutions for many of the new operational conditions posed with gelled fuels will help future programs run more smoothly. The major factors that influenced the success of the testing were propellant settling, piston-cylinder tank operation, control of self pressurization, capture of metal oxide particles, and a gelled-fuel protective layer.

In these ongoing rocket combustion experiments at the NASA Lewis Research Center, metallized, gelled liquid propellants are used in a small modular engine that produces 30 to 40 lb of thrust. Traditional liquid RP-1 and gelled RP-1 with 0-, 5-, and 55-wt % loadings of aluminum are used with gaseous oxygen as the oxidizer (ref. 1). The figure compares the thrust chamber efficiencies of different engines.




*Comparison of rocket engine performance for four fuels: RP-1, and 0-, 5-, and 55-wt % RP-1/Al.*

## Propellant Settling

After the gelled fuels are mixed and before this mixture is put in the propellant transfer tank, the RP-1/Al must be stirred vigorously. During storage periods of 1 to 10 days, the metal particles in the fuel begin to settle because of gravity, and a thin layer of clear RP-1 forms atop the fuel in its storage can. The fluid layer is about 1-cm thick after about 10 days of storage. Ostwald forces (refs. 2 and 3) promote clumping of the propellant during storage.

## Using a Piston-Cylinder Tank

In previous testing of gelled fuels (ref. 4), there was some difficulty in feeding the metallized gelled JP-10/Al into the piston-cylinder tank. A manual stirring process was

used to reduce the viscosity of the thixotropic fuel until a small pump could feed fuel into the cylinder. To speed up this time-consuming filling process, we fabricated a pressurized transfer tank to fill the piston-cylinder tank. The transfer tank was charged with gelled fuel, and nitrogen pressurant was used to flow the fuel to the cylinder.

# Propellant Self Pressurization

Experiments were conducted after we had an unplanned pressurization of the piston-cylinder tank. The propellant had been in the cylinder for several days to several weeks, and the tank pressure had risen from zero to several hundred pounds per square inch (gravimetric). In our testing operations we were unsure as to the fluid interactions, but high-pressure gas is generated when RP-1/Al is exposed to water. To alleviate this problem for the short term, we replaced the "pressurizing" fluid for the gelled propellant with hydraulic fluid. A series of tests that estimate the gas-generation rate from a mixture of RP-1/Al metallized gelled fuel and a test fluid were conducted. The test fluids were water, hydraulic fluid, and Solvent 140. Although Solvent 140 and hydraulic fluid generated little or no pressure, the water exposed to the RP-1/Al created significant pressures in some cases.

# Particle Capturing

Rocket testing in Lewis' Cell 21 uses a 9-ft-long tubular diffuser with a series of circumferential water spray nozzles for cooling. This diffuser tube was augmented with an add-on tube (that added 3 ft of length) and a 150-gal plastic tank to capture water from the cooling system and particles from the rocket exhaust. During a firing, the top of the tank was removed and the gaseous exhaust products were vented vertically away from the test cell. The water captured in the tank was run through a 10-micrometer filter before the water was exhausted into the laboratory area drain system. A small fraction of the metal particles were exhausted in this manner, but the bulk of the Al2O3 and other solid combustion products were captured in the cooling water flow. The filter did foul after a period of several days of testing, and when it fouled, it had to be changed. During the entire 1-year test period, we changed the filter at least 8 to 10 times.

# Gelled Propellant Protective Layer

During testing with the gelled RP-1 and the 5-wt % RP-1/Al, some residual propellant was found in the rocket chamber, coating the entire injector face and all the chamber walls. This residual propellant was actually a mix of unburned fuel (with a gray or clear pink color) and some black or combustion products. Although none of the injector ports clogged, there was a potential for the gel to obstruct the ports to a small degree. Once this thin layer was removed with a soft cloth, the metal surfaces exhibited minimal erosion. An improved cooling technique might be derived from this effect. The thickness of the layer is 1 to 2 mm for 0- and 5-wt % RP-1/Al. The layer is easily wiped off with a soft cloth when the face is cleaned after disassembly. The gel layer also coats the injector such that the O2 and fuel flow form holes in the layer.

# References

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